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# STRENGTH ANALYSIS OF E-GLASS AND JUTE FIBER REINFORCED POLYESTER COMPOSITES

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***ABSTRACT***

***Nowadays, composites have been a wide area of research due to their better characteristics like strength to stiffness and weight to strength abilities. These properties lead composites to use in various application fields such as automotive, aviation, sporting and marine industries. Always composites are continuous lookout for analyzing without compromising on their physical and mechanical behavior. In this work, fibre reinforced composites were manufactured using E-glass and jute fiber with polyester as reinforcement. The composite laminates are prepared with 60:40 fibre-resin volume fraction percentages. The mechanical strength parameters such as flexural strength, tensile strength, interlaminar shear strength [ILSS] and impact strength of the composite laminate are studied as per the ASTM standards.***

***KEYWORDS: E-Glass, Jute, Interlaminar Shear Strength [ILSS] & Impact Strength***

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## 1. INTRODUCTION

Fiber reinforced plastics (FRP) are receiving wide attention lately, because they have many attractive mechanical characteristics. Composites are engineering materials made up of two or more constituents to form a single bulk mass [2]. There are number of options for matrix and reinforcing materials and they can be manufactured with various combinations, percentages and orientations to obtain a composite material with required properties [3]. In order to produce an optimized design, it is essential to evaluate the composite material for its properties like, tensile strength, flexural strength, impact resistance and interlaminar shear strength (ILSS).

Fiber reinforced plastics are most every now and they are utilized in aerospace structures, marine segments and automobile fields henceforth mechanical strength, damage tolerance and damage resistance are more essential features under static and dynamic loading, in light of the fact that they experience or exposed to unplanned impact loads [4]. Among these impact conditions, the low-velocity impact induced damages, delamination is the dominant failure mode and may cause severe damage of the structural strength when the structure is under a compressive load [5]. Many researchers have been carried out to understand the mechanism of delamination and the effect of delamination on the performance of composite laminates under various loading conditions [6, 7].

As mentioned in the above statement, composite materials are having high strength - weight ratio due to manufacturing difficulties, but they may contain voids, cracks and inclusions  and these lead to failure within the

specified tolerance. To overcome this drawback, these materials have drawn into fibers which may have flaws, but few of the perfect once in a bundle will help for predicted strength characteristics [8]. Matrix system spreads the load between fibers and protects the fibers against abrasion, wear and impact. Properties of resulting composite will combine the characteristics of resin systems and fibers, both, thus exhibiting many useful properties like high tensile strength, high stiffness, high fracture toughness, and impact etc. [9]. The properties of PMCs can be varied, depending on functional requirements, with the change of orientation, length, type, concentration of fibers and properties of resins used [10]. This research work is focused on the study of strength parameters glass/polyester and jute/polyester composites under static and dynamic loading conditions as per ASTM standards.

## II. MATERIALS AND FABRICATION

Extensive literature survey leads us to take up this study of composite material under different loading conditions. It has been analyzed from literature that, most of the work is carried on carbon and Kevlar fibre with epoxy as reinforcement to form laminated composites to obtain desired mechanical characteristics. Hence there is a choice to select naturally available fibre like jute and synthetic fibre like glass as reinforcing material and polyester as matrix to study the mechanical behavior, because little amount work has been carried out on naturally available fibres with polyester as reinforcement.

Commercially available unsaturated polyester resin, jute fabric and woven glass fabric is used for this present study. Hand lay up technique is used for fabrication of to obtain woven fibre mat (E-glass, Jute) reinforced polyester laminate. Initially the mould surface is cleaned with acetone, allowed to dry and a thin layer of polyvinyl acetylene is applied on the mould as releasing agent for easy removal of the laminate after curing. Same time jute and E-glass fabrics are cut into the required dimensions ($300\times300$ mm$^2$). Unsaturated Polyester resin is prepared by adding catalyst that is Methyl Ethyl Ketone Peroxide (MEKP) and accelerator (Cobalt) 2% each. Once a layer of resin is applied on the mould, a single woven fabric layer is placed on it and it continues until all layers. The air bubbles are removed and the layers are consolidated by squeezing using the hand roller. Finally the mould is closed and allowed to cure for 24 hours. The 2.2 and 6 mm laminates are fabricated using 4 and 12 layers of woven glass fabric reinforced polyester resin laminate and 2.4 and 6.5 mm laminate are fabricated using 3 and 10 layer of jute fabric reinforced polyester resin.

The composite laminates were cut into pieces with the required dimensions using a cutting machine with a diamond-coated saw. Specimens were finished by the abrasive paper (Emery paper) and dimensions were measured by vernier calliper. The tests are conducted as per ASTM standards.

## III. EXPERIMENTAL WORK

Mechanical characterizations of the developed composite laminates are studied using following experimental work.

**Tensile Test:** The tensile properties of the bidirectional composite laminate samples are determined according to ASTM D3039 standard [11]. The specimen dimension and cross head speeds (2mm/min) were chosen according to ASTM standard. A tensile test is carried out by placing the samples in the universal testing machine (UTM) and tensile load is applied continuously until specimen failure. The longitudinal tensile strength and young's modulus are determined without strain gauge bonded. The total 12 number of specimens were prepared for tensile test of different reinforced fiber (Glass and Jute fiber) and are shown in Figure.1.

**Figure 1: Tensile Specimens**

**Flexural Test:** The flexural coupons are preferred as per the ASTM D790-02 [12] are as shown in Figure.2. The shapes of the specimens are rectangular having different dimension according to thickness. The span length of the specimen is 96mm and 54mm for the specimen thickness 6 and 2 mm respectively. Flexural test was conducted using three point bend fixture and the cross head speed of 1.3mm/min. Force and deflection data are obtained by computer controlled UTM.

**Figure 2: Specimens for Flexural Test**

**Interlaminar Shear Strength Test (ILSS):** The interlaminar shear strength test is performed according to ASTM D3846 to measure the interlaminar shear strength of composites [13]. The test speed set to 1 mm/min and specimen dimensions are shown in Figure.3. This test provides the shear strength between the laminas of the composite material. The test is conducted in compression mode by placing specimen between the fixtures to restrict the buckling.

**Figure 3: Specimens for ILSS Test**

**Impact Test:** The impact test was conducted using Izod / Charpy impact testing machine. The test samples are prepared as per ASTM D256-02 [14]. The notched specimens were loaded in the izod impact testing machine, pendulum is allowed to until it fracture or breaks. Using the impact test, the energy absorbed by the material can be measured in yield strength, fracture toughness of the material. Length of all the specimens tested was 55 mm and width 12.5 mm. The other dimensions are shown in Figure.4.

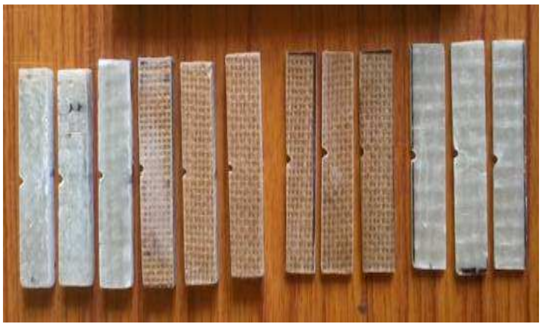

**Figure 4: Specimens for Impact Test**

## RESULTS AND DISCUSSIONS

Tests are conducted as per the ASTM standards discussed in earlier sections. The obtained results obtained are discussed in this section.

**Tensile Properties:** Woven glass and jute fiber reinforced polyester matrix specimens were tested according to test procedure described in the earlier section and determined the longitudinal tensile strength, modulus of elasticity and fracture energy using equation 1,2 and 3 respectively. Test results of longitudinal tensile specimens are shown in Figures.5 (a, b, c and d). The load carried by 6 mm thick glass/polyester composite shown maximum than 2.3 mm thick specimens in Figure.5 (a, b). But tensile strength for both specimen thicknesses is applicably same. Jute/polyester also follows the same in first condition, but comparing the tensile strength 2 mm thick, 11.18% is higher. The strain was found to be more in 6 mm thick specimens of both materials.

Specimens failed at maximum load capacity as shown in the Figure.5 (a). The specimens were failing when maximum tensile strength was reached. Failure was observed perpendicular to the loading direction.

Tensile strength = Max force/area (1)

$$\text{Elastic modulus (E)} = \frac{\sigma 2 - \sigma 1}{(\varepsilon 2 - \varepsilon 1)} \quad (2)$$

Fracture Energy=Area under load displacement curve= Half the triangle=0.5×L×P (3)

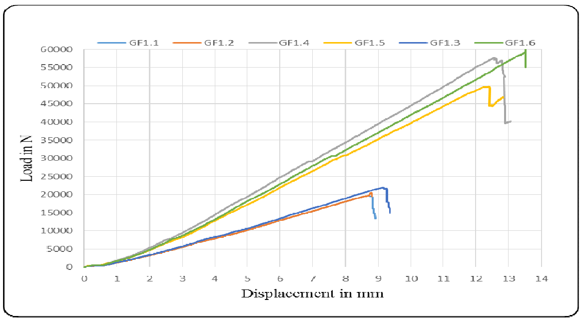


**Figure 5(a): Load History of 2mm and 6mm Glass/Polyester Composite**

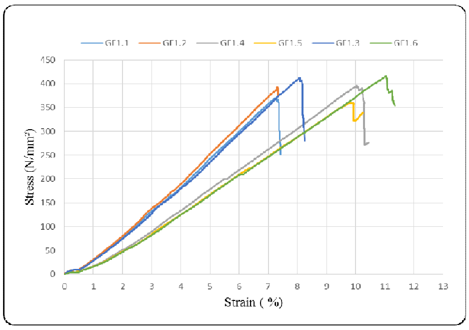


**Figure 5(b): Stress-Starin History Glass/Polyester Composite**

Figure.5 (a) shows that, load varies linearly with displacement and sudden drop in load was found at ultimate strength of the material. Maximum load was found in 6 mm (load = 55870N) and minimum was 2 mm (load =20804) thick glass/polyester composite. Figure.5 (b) shows the ultimate strength of the material and these were mentioned in Table 1.

The tensile strength of the 2 mm and 6 mm thick specimens made of the same material was 381 MPa, but percentages of strain were a bit different on an average of 7.6 and 10.5 % respectively.

Figure. 5(c) and 5(d) belongs to jute/polyester composites and there was a difference between load carried by 2 and 6 mm thick specimens having loads 3060 and 7388 N respectivaly. The maximum tensile strength of 2 mm thick JFRP composite was 11.1% more than 6 mm thick JFRP composite and strain in 2 and 6 mm thick JFRP were almost equal to on an average of 4.5% (Figure.5 (d)). The properties obtained from the tensile test are presented in Table 1.

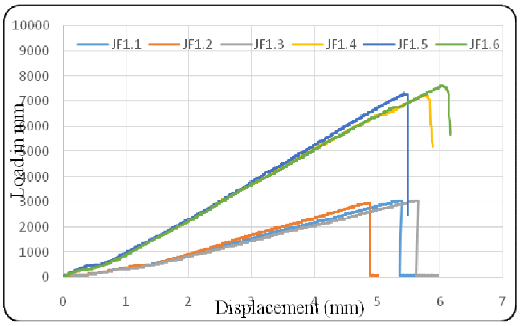


**Figure 5(c): Load History of 2mm and 6mm Jute/Polyester Composite**

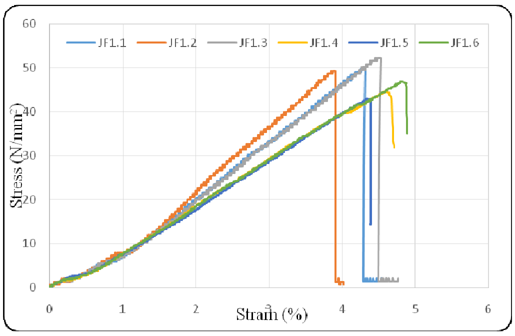


**Figure 5(d): Stress-Starin History Jute/Polyester Composite**

**Table 1: Properties of Glass and Jute Polyester Composites**

| Material | Thickness (mm) | Modulus of Elasticity (GPa) | Ultimate Tensile Strength (MPa) | Tensile Fracture Energy (J) |
|---|---|---|---|---|
| Glass/polyester | 2 | 25.66 | 381.64 | 85 |
| Glass/polyester | 6 | 25.37 | 381.8 | 373.7 |
| Jute/polyester | 2 | 6.25 | 51.79 | 12.2 |
| Jute/polyester | 6 | 6.16 | 46.58 | 48 |

**Flexural Properties:** Failure occurs due to matrix cracking, fiber breakage and delamination at the compression side, as shown in Figure.6 (a). The flexural strength and strain is calculated using equations 4 and 5. The maximum load and deflections are obtained from the load data graph as shown in Figure.6 (a) and 6 (c).

$$\text{Flexural stress} = (3PL)/ (2bd^2) \tag{4}$$

$$\text{Flexural strain} = (6Dd)/L^2. \tag{5}$$

$$\text{Flexural modulus} = (L^3m)/ (4bd^3) \tag{6}$$

Woven glass and jute fiber reinforced polyester matrix specimens were tested using following test procedures described in the section to determine the flexural modulus of elasticity ($E_{flexural}$). Test results of flexural modulus specimen is as shown in Figure.6 (a, b, c and d).

The flexural stress increases steeply with deflection until observed maximum force. The maximum force is found at 6 mm thick specimen and fiber failed due to tensile stress at the outer layer and compression at the top. Maximum flexural stress was found in 2 mm thick laminate (648 MPa) and maximum load carried by 6 mm thick laminate (3657.05 N) and strain in 2 and 6 mm thick specimens were almost same for GFRP composite, shown in Figure.6 (b). The minimum flexural load was found 2 mm thick GFRP composite (521 N) and flexural stress was 5.66% higher than 6 mm thick specimen.

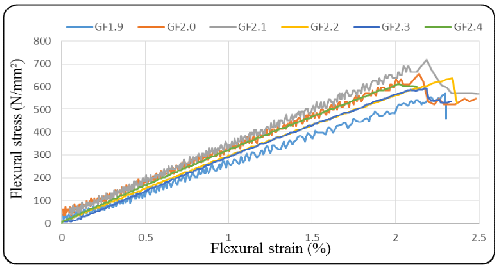


**Figure 6 (a): Flexural Load of Glass/Polyester**

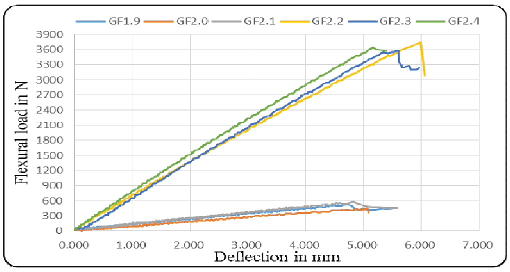


**Figure 6 (b): Flexural Strength of Glass/Polyester**

The flexural load v/s deflection curve for JFRP composite is shown in Figure.6 (c). The deflection of 6.5 mm and maximum load of 854.22 N was found in 6 mm thick laminate and flexural strain was also found to be 30% higher than 2 mm thick JFRP composite (Figure.6 (d)).

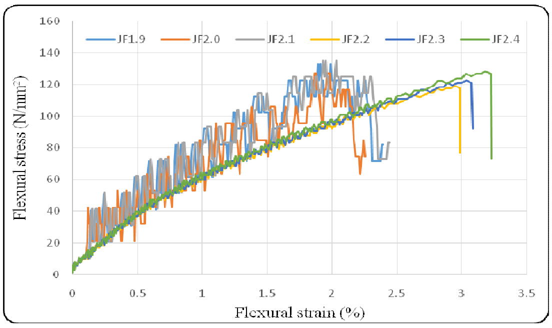


**Figure 6 (c): Flexural Load of Jute/Polyester**

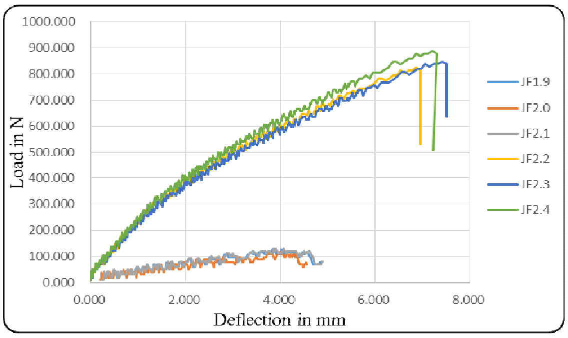


**Figure 6 (d): Flexural Strength of Jute/Polyester**

**Interlaminar Shear Strength Properties:** The shear properties of bidirectional woven fabric material were tested for ILSS. To determine ILSS of composite specimens were tested according to the ASTM D3846-02. Specimen dimensions were measured by vernier calliper and were shown in Table 3 Specimens was tested according to test procedure mentioned in section to determine the failure load. ILSS is calculated using equation 7 and Shear properties of the specimens is represented in the Table 2.

$$\text{ILSS} = \frac{3}{4}\left(\frac{P\max}{wt}\right) \qquad [7]$$

Where,

Max, is maximum load carried by the specimen,

W is the width of the specimen, it is the thickness of the specimen.

Interlaminar shear strength obtained is in agreement with the previous author [18] (ILSS was 34MPa). ILSS of glass/polyester is 14 % greater than jute/polyester for the same thickness. The debonding between the layers is due to mode II shear loading. The specimens failed between the two mid layers.

**Table 2: ILSS Property of Tested Specimens**

| Composite Material | Specimen Code | Shear Area ($mm^2$) | Max. Load (N) | ILS Strength (MPa) |
|---|---|---|---|---|
| **Glass/polyester** | GF2.8 | 79.3 | 4247 | 40.16 |
| | GF2.9 | 79.9 | 4138 | 38.84 |
| | GF3.0 | 85.8 | 4236 | 37.0 |

| | | | | |
|---|---|---|---|---|
| **Average ILLS strength** | | | | **38.66** |
| **Jute/polyester** | JF2.8 | 87.1 | 4140 | 35.6 |
| | JF2.9 | 81.5 | 3665 | 33.72 |
| | JF3.0 | 89.0 | 3774 | 31.8 |
| **Average ILLS strength** | | | | **33.7** |

The compressive load carried by the GFRP (4207 N) composite and JFRP (3859 N) composite was almost equal (Figure 7 (a) and 7 (b)) and interlaminar shear strength of GFRP was 14.7% greater than JFRP having same thickness specimens (Table 7 (a)). From this it is observed that, ILSS depends on matrix material rather than fiber.

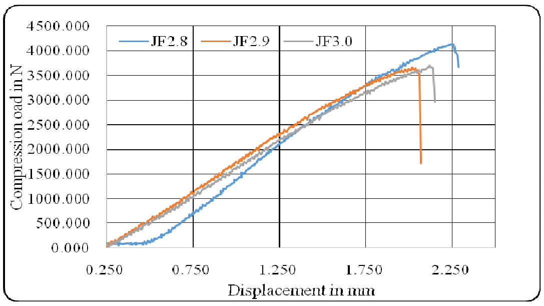


**Figure 7 (a): Variation of load with respect to displacement of 6 mm thick Glass/polyester composite**

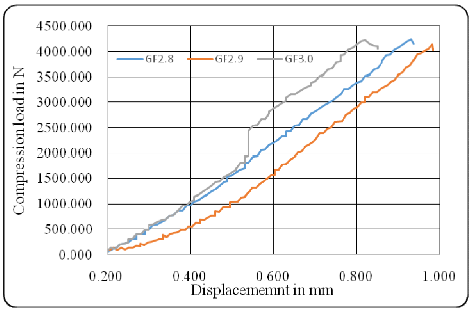


**Figure 7 (b): Variation of load v/s deflection of 6 mm thick Jute/polyester composite**

**Izod Test Results:** In this test, energy absorbed by the specimen after impact was recorded. The energy release rate calculated using the equation 8 which was used by authors [19]. Shape factor was not considered, because spring effect was neglected.

$$Gc = \frac{U}{BW\varphi(a/w)} \qquad (8)$$

Where,

Gc =Energy release rate (J/mm$^2$),

U = Absorbed impact energy, B is material width (mm),

W = the height of the material specimen (mm),

φ (a/w) = shape factor of the specimen to minimize the spring effect of arc shape according to the changing depth ratio (Neglected)

The absorbed energy, impact resistance and energy release rate were calculated and presented in the Table 3. The impact energy absorbed and energy release rate of 6 mm thick woven glass reinforced polyester composite is 7.4 Joules and the least is 0.43 Joules for 2 mm thick jute/polyester composite (Figure.8 (b)). The specimens failed at the notched area.

**Table 3: Absorbed Energy and Energy Release Rate of Impacted Specimens**

| Composite Material | Specimen Code | C/S Area ($mm^2$) | Absorbed energy (Joules) | Impact resistance ($J/m^2$) | Energy Release Rate($J/mm^2$) |
|---|---|---|---|---|---|
| Glass/polyester | GF3.1 | 10×2.2 | 7.2 | 554.6 | 0.32 |
| | GF3.2 | 10×2.2 | 7.2 | 570.0 | 0.32 |
| | GF3.3 | 10×2.2 | 7.8 | 600.0 | 0.35 |
| **Average Value** | | | **7.4** | **574.66** | **0.33** |
| Glass/polyester | GF3.4 | 10×6 | 37.6 | 2820 | 0.62 |
| | GF3.5 | 10×6 | 36.9 | 2767.5 | 0.61 |
| | GF3.6 | 10×6 | 37.8 | 2835 | 0.63 |
| **Average Value** | | | **37.4** | **2817.5** | **0.62** |
| Jute/polyester | JF3.1 | 10×2.4 | 0.4 | 30.00 | 0.016 |
| | JF3.2 | 10×2.4 | 0.5 | 30.50 | 0.020 |
| | JF3.3 | 10×2.4 | 0.4 | 30.81 | 0.016 |
| **Average Value** | | | **0.43** | **30.43** | **0.017** |
| Jute/polyester | JF3.4 | 10×6.5 | 1.8 | 138.6 | 0.027 |
| | JF3.5 | 10×6.5 | 1.9 | 138.6 | 0.029 |
| | JF3.6 | 10×6.5 | 2.1 | 138.6 | 0.032 |
| **Average Value** | | | **1.8** | **138.6** | **0.029** |

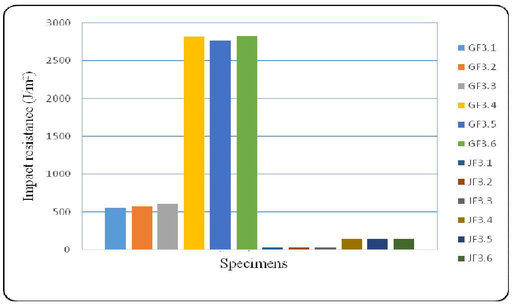


**Figure 8 (b): Energy Absorbed by Specimens**

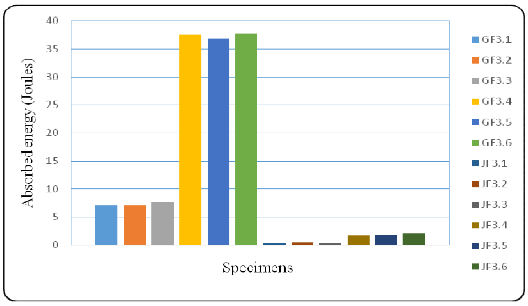


**Figure 8 (c): Impact Resistance of Specimens**

The impact resistance offered by the GFRP specimens was found to be higher than JFRP specimens. Impact resistance was very lower for 2 mm thick JFRP specimens. Figure. 8 (c) also reveals that, impact resistance is higher for thicker specimens and it also depends upon the type of fiber used.

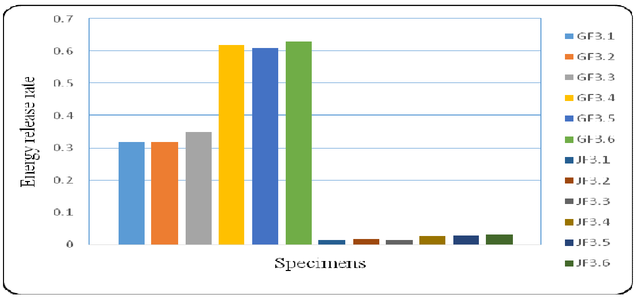


**Figure 8 (d): Energy Relese Rate of All Specimens**

The energy release rate was found maximum in GFRP composite and minimum in JFRP. The energy release rate of 6 mm thick specimens is approximately two times the 2 mm thick specimens made from GFRP Composite.

## CONCLUSIONS

The result obtained from the experimental work clearly proves that the performance of E-glass fibre reinforced polyester composite (GFRP) is better than jute fibre reinforced polyester composite (JFRP) laminates. But JFRP laminates can be utilized as an alternate when strength required is low due to its biodegradable nature, cheaper price and availability. It is also seen from the experiments that tensile strength, flexural strength, energy absorbed and young's modulus of the GFRP laminates is very much higher than the JFRP. But the interlaminar strength of the laminates is mainly depending on

matrix rather than fibre because it depends on the bonding between the matrix and fibre. The most Common failure modes observed in laminates are matrix cracking, fibre breakage and delamination**.**

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